Appendix E

ALTERNATE METHODS FOR CALCULATING SALT LOADING FROM THE NORTHWEST SIDE OF THE LOWER SAN JOAQUIN RIVER SUB-AREA

I. INTRODUCTION

This appendix summarizes two alternate methods used to calculate salt loading from the Northwest Side of the Lower San Joaquin River Watershed. The original method is a surface water mass balance, where salt loading from the Northwest Side is determined by subtracting the sum of the salt loads from all other geographic sub-areas in the Lower San Joaquin River Watershed from the river's total salt load at Vernalis. The first alternate method involves calculating the total annual salt load from the Orestimba Creek watershed and applying the Orestimba Creek unit area loading to the larger Northwest Side Sub-area. The second alternate method is to calculate the total loading for Northwest Side Sub-area using loading values from discrete discharges to the Lower San Joaquin River from subsurface drains, surface return flows and ephemeral tributaries. Based on these methods the annual average salt load from the Northwest Side ranged from 280,000 tons/year to 321,000 tons/year, when considering both ground and surface water salt contributions.

II. BACKGROUND:

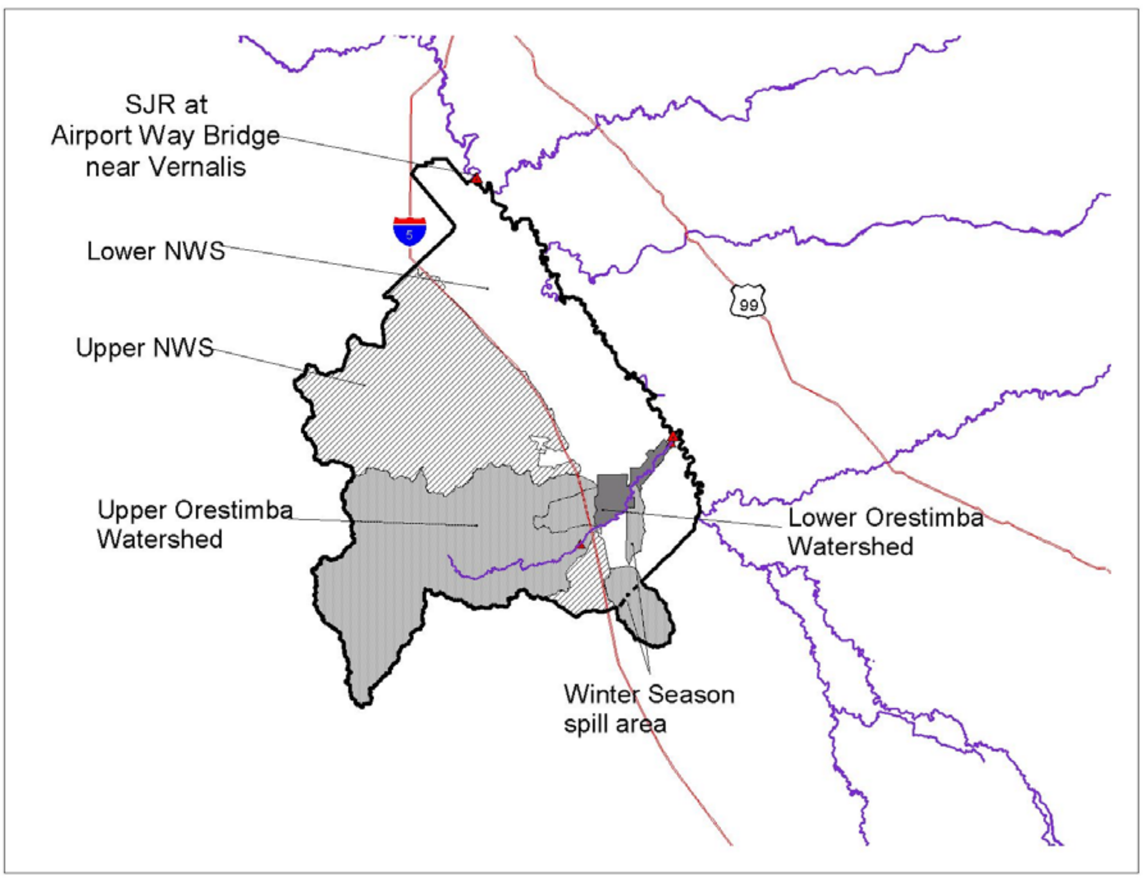
For TMDL planning purposes, the Lower San Joaquin River (LSJR) has been divided up into seven major geographic sub-areas. As its name suggests, the Northwest Side (NWS) Sub-area occupies approximately 365,000 acres in the northwest section of the LSJR Basin. The NWS Sub-area is located in portions of San Joaquin and Stanislaus counties. Orestimba Creek, Del Puerto Creeks, Hospital/Ingram Creek, and other creeks drain the sub-area. These creeks flow intermittently during the rainy season, and are dominated by irrigation return flows during the summer. Communities in the NWS Sub-area include Newman, Crows Landing, Patterson, Westley, and Vernalis. There are approximately 118,000 acres of agriculture within the NWS, according to the Regional Board's Geographic Information System (GIS) analysis, which is primarily based on the CA Dept. Of Water Resource's Land Use Information Survey data. Water supply and drainage is provided by numerous public water agencies within the sub-area, including Patterson W.D., West Stanislaus I.D., Del Puerto W.D., C.C.I.D., and El Solyo W.D.

Complex drainage and water supply operations coupled with a lack of long-term flow and water quality data for most of the creeks and drains in the NWS Sub-area make it difficult to characterize the salt and boron loads originating from the NWS Sub-area. Long-term flow and water quality data is available for the San Joaquin River at Vernalis (downstream of the NWS Sub-area) and for five of the six additional sub-areas that discharge to the LSJR upstream of the NWS Sub-area. Salt loading from the East Valley Floor Sub-area (the sixth sub-area) is also estimated based on data from the Harding Drain. A surface water mass balance method is used to estimate salt loading from the NWS Sub-area by subtracting the sum of the loads from the six contributing upstream sub-areas from the total load at Vernalis. This method yielded a NWS Sub-area salt load estimate of approximately 320,000 tons/year for the 21-year period of record for water-years 1977 through 1997. Based on this method, the NWS Sub-area accounts for approximately 30% of the river's total salt load as measured at the LSJR at the Airport Way Bridge near Vernalis.

Regional Board staff presented these findings to the public during staff workshops held in 2000 and 2001. Staff received extensive public comments indicating that the estimate of salt loading from the NWS Sub-area was too high. Based on these public comments and uncertainties in the original analysis, the salt loading estimate for the NWS Sub-area is re-evaluated using two alternate loading estimates.

III. ORESTIMBA EXTRAPOLATION METHOD (Alternate method 1):
The Orestimba extrapolation method is a method of calculating the salt loads from the NWS Sub-area based on the salt loads from Orestimba Creek. This method is based on the assumption that the Orestimba Creek watershed is representative of the entire NWS Sub-area, and that the unit area salt loading from areas with the Orestimba Creek watershed are similar to those within the rest of the NWS Sub-area. The Orestimba Creek watershed is the single largest drainage basin in the NWS Sub-area and it is approximately 105,000 acres, which represents about 28 percent of the drainage area within the NWS Sub-area (figure E-1).

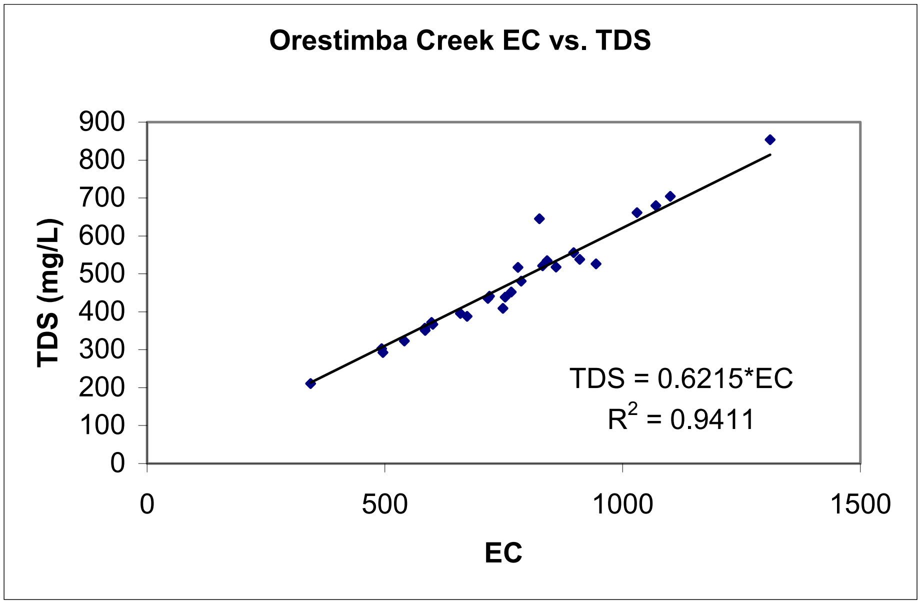
Figure E-1 Northwest Side of the Lower San Joaquin River



Appendix E

Relatively good water quality and flow data are available for Orestimba Creek at River Road, which is a downstream site located about one mile above the creek's confluence with the LSJR. Flow data is also available for Orestimba Creek near the California Aqueduct, which is considered an upstream site in this analysis. All of the data used to calculate loads was obtained from the USGS. Daily mean flow and EC data was used to calculate daily and annual loads for the two sites on Orestimba Creek. No water quality data was available for the upstream site and EC value of 300 μS/cm was used to calculate upstream loads. The 300 μS/cm value was based on best professional judgment and evaluation of the sparse data set that was available for the upstream site and other sites located along the upper eastern side of the Coastal Range (Westcot, 1991). A site-specific conversion factor of 0.61 is used to convert EC (μS/cm) to TDS in milligrams per liter (figure E-2). The raw water quality and flow data used to calculate loads is available in digital format on request.

Figure E-2. Lower Orestimba Creek Site specific EC to TDS conversion factor



In order to determine loading from the NWS, the Orestimba Creek watershed is partitioned into an upper and a lower section. The upper watershed is considered to be the Orestimba Creek drainage area above the California Aqueduct. This section of the watershed is generally above all of the major agricultural areas in the NWS Sub-area and it is approximately 105,326 acres in size (figure E-1). This upper section of Orestimba Creek was assumed to be representative of the remainder of the NWS Sub-area above the California Aqueduct. Daily loads for the upper Orestimba Creek were calculated for water years 1993-1997 with flow data from USGS site 11274500, Orestimba Creek near Newman, Ca. (Table E-1).

The lower watershed is considered to be the Orestimba Creek watershed below the California Aqueduct. Daily and annual loads for the lower Orestimba Creek watershed were calculated using daily flow and water quality data collected from USGS site 11274538, Orestimba Creek at River Road. Loading data from the upstream site

(11274500) was subtracted from the downstream site to determine the loads that originated within the lower Orestimba Creek Watershed. The lower Orestimba Creek watershed primarily consists of agricultural areas and ranges in size from 6,904 (Mar.-Dec.) to 19,777 acres (Jan-Mar). The temporal size difference of the watershed is due to winter season spill over from the CCID main canal and agricultural areas located on the northern periphery of the NWS Sub-area. According to USGS personnel, there are approximately 12,873 acres of land that only drain to the lower river during January through March. Consequently, the loading from the lower Orestimba Creek watershed was divided into a winter season load (Jan.-Mar.) and a load for the remainder of the year (Table E-1).

Table E-1. Orestimba Creek Salt Loading (in tons)

Water Year	Upper Watershed Load (All Year)	Lower Watershed		Total
		Winter season (Jan-Mar)	Rest of the Year (Apr-Dec)	
1993	8,035	6,429	3,453	17,917
1994	3	5,419	1,514	6,936
1995	7,960	6,197	6,965	21,122
1996	5,961	5,172	4,625	15,758
1997	8,773	5,904	13,855	28,532
Mean	6,146	5,824	6,082	18,053

A GIS was used to determine the size of the upper Orestimba Creek watershed, the lower Orestimba Creek watershed, and the winter season lower Orestimba Creek watershed. The GIS was also used to determine the size of the NWS Sub-area above and below the California Aqueduct, which roughly divides the sub-area into an upper coastal range area and lower agricultural area (Table E-2).

Table E-2. Geographic Areas (in acres)

Upper Orestimba watershed	105,326
Lower Orestimba watershed	6,904
Lower Orestimba watershed-winter season*	19,777
Upper Northwest Side (above the CA Aqueduct)	220,826
Lower Northwest Side (below the CA Aqueduct)	124,811
Winter Season* Lower Northwest Side (below the CA Aqueduct)	134,744
*Winter Season is Jan-Mar	

The upper NWS Sub-area is divided by the upper Orestimba Creek watershed area to develop an area-ratio that is used to apply the upper Orestimba Creek watershed loading values to larger upper NWS Sub-area. Similarly, the lower NWS Sub-area area is divided by the lower Orestimba Creek watershed to develop an area-ratio that is used to apply the lower Orestimba Creek watershed loading values to larger lower NWS Sub-area (Table E-3). For example, the upper NWS Sub-area is roughly twice as big as the upper Orestimba Creek watershed, so we would expect the loads from the upper NWS side to be about twice as large as the loads from upper Orestimba Creek. This process is analogous to developing a unit area load for the upper and lower Orestimba Creek watersheds and then applying those unit area loads to the respective upper and lower NWS areas.

Table E-3. Determination of NWS Sub-area Area-Ratios

Portion of Northwest Side	Column A Area (acres)	Column b Corresponding Orestimba Acreage	Area-Ratio (=Column A/ Column B)
Upper NWS (above California Aqueduct)	220,826	105,326 (Upper Orestimba)	**2.1**
Lower NWS (Apr-Dec) (below California Aqueduct)	134,745	6,904 (Lower Orestimba Apr-Dec)	**19.5**
Winter Season Lower NWS (Jan-Mar) (below California Aqueduct)	134,745	19,777 (Lower Orestimba Jan-Mar)	**6.8**

Each of the area-ratios are multiplied by the corresponding Orestimba Creek salt load to determine the total load for the upper NWS Sub-area, the lower NWS Sub-area and the Lower winter season NWS. The loads from each of these areas were added together to determine the total load from the entire NWS Sub-area (Table E-4). Total average annual salt loading from NWS Sub-area surface water discharges is estimated to be approximately 162,694 tons per year using the Orestimba extrapolation method. This estimate does not include groundwater salt contributions from the NWS Sub-area.

Table E-4. Calculated Salt Loading From the NWS

SECTION OF NWS	Corresponding Orestimba Creek Load	Area-Ratio	NWS Sub-area Load
Upper NWS (above California Aqueduct)	6,146	2.1	12,907
Lower NWS (below California Aqueduct)	6,082	19.5	118,599
Winter Season Lower NWS (below California Aqueduct)	5,824	6.8	39,603
		Total Loading From NWS	**171,109**

IV. <u>DISCRETE DISCHARGE METHOD (Alternative 2):</u>
This section describes a second method used to quantify how much salt and boron is discharged to the LSJR from the NWS sub-ara using salt loading data from four major types of sources: 1) agricultural surface water drainage; 2) agricultural tile water drainage; 3) ephemeral stream flow from natural runoff; and 4) waste water treatment discharge. The goal of this analysis is to arrive at a reasonable load estimate for the entire NWS Sub-area relative to other sub-areas in the LSJR Basin, and not necessarily to quantify loading on the district and smaller scale. The only major source not evaluated in this section is ground-water inflow to the LSJR, which includes water derived from both natural runoff and agricultural drainage. This load is estimated in Section V.

Because of limited monitoring data, many assumptions and estimates are necessary to fill in data gaps. A lot of the agricultural data is derived from a limited number of measurements in 1987, so discretion is needed when applying it to today's conditions.

In the following sections, load estimates are made separately for each of the four types of sources in the NWS. The estimates cover the irrigation season, defined as April through September, and the non-irrigation season, defined as October through March. Annual loads are also computed, which cover both seasons. Table E-5 below summarizes the load contributions from the various sources.

Table E-5: Summary of Load Contributions to the San Joaquin River from Various Sources in Northwest Section

		Non-Irrigation Season (Oct - Mar)			Irrigation Season (April - Sept)			Annual		
Source	Total Area (acre)	Flow (AF)	Salt Load (tons)	Boron Load (lbs)	Flow (AF)	Salt Load (tons)	Boron Load (lbs)	Flow (AF)	Salt Load (tons)	Boron Load (lbs)
Surface Water Drainage	118,045	18,472	20,114	38,161	118,945	81,544	149,180	137,417	101,659	187,341
Tile Water Drainage	9,360	969	1,771	3,030	6,241	11,403	19,514	7,210	13,174	22,544
Ephemeral Streams	249,536	23,553	10,336	28,579	3,834	4,776	14,475	27,388	15,113	43,054
TOTAL	376,941	42,995	32,222	69,771	129,020	97,723	183,169	172,015	129,945	252,940

The total annual salt load from the NWS Sub-area is 129,945 tons. Most of this arrives during the irrigation season (97,723 tons) when agricultural discharge is high, and a lesser amount comes during the non-irrigation season (32,222 tons) when watershed runoff to ephemeral streams make up an increased proportion of the load (although agricultural area is still the dominant source). During the irrigation season, surface water plus tile water drainage composes 95 percent of the total load. During the non-irrigation season, they compose only 68 percent of the total load, whereas the ephemeral stream componant is 32 percent. Because relatively few acres are tile drained (9,360 acres), tile water drainage represents only 10 percent of the total annual salt load (which is 11.5 percent of the total agricultural load). (It should be noted again, that this section does not cover groundwater salt contribution, which is also a substantial source.)

The total boron load is 252,940 pounds. The boron load is more evenly split between the irrigation and non-irrigation season: 183,170 pounds during the irrigation season and 129,020 during the non-irrigation season. During the irrigation season, agricultural surface water plus tile water drainage composes 92 percent of the total load. During the non-irrigation season, they compose 59 percent of the total load, whereas ephemeral stream contribution is 31 percent.

Two wastewater treatment plants (WWTP), Newman and Patterson, discharge directly to agricultural fields. They cannot be considered as a separate load to the LSJR because their loads will appear in the agricultural surface water drainage and tile drainage numbers. The annual amount of salt discharged from these WWTPs to land in 1999 was 5,084 tons, which represents 4.4 percent of the total agricultural load. In other words, of the total annual salt discharged by agriculture in the NWS Sub-area to the LSJR, 4.4 percent of this is derived from the WWTP's.

1. Agricultural Surface Water Drainage

Loading from surface water drainage is based on 1987 flow measurements for various drainage areas in the NWS. Flows were measured in 1987 at fifteen major drains (Table E-6), as part of the Regional Board sampling program (Rashmawi, E.A., et al 1989). Generally, they consist of instantaneous daily readings made once per month. For July and August, more detailed measurements were made that indicate flow can vary greatly depending on the hour of the day. In this analysis, the large variations for individual drains should to some degree cancel each other out as they are summed, so the total flow calculated for the entire sub-area will not be strongly influenced by individual drain fluctuations.

Table E-6. Observed Agricultural Surface Flow Drainage To The San Joaquin River 1987 From the Northwest Side (acre-feet)

		Non-Irrigation Season (Oct - Mar)						Irrigation Season (April - Sep)						Non-Irrig. (Oct - Mar)		Irrigation (April-Sep)	
Rivermile	Location(s)	1986 Oct	Nov	Dec	1987 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Monthly Avg^ (AF)	Season Total** (AF)	Monthly Avg (AF)	Season Total** (AF)
119	Hills Ferry Road Drain (Newman Wasteway)#								242	272	437	299				312	1,873
117	Azevedo Road Drain	2.7	0.3		0.7	0.5			45	242	60	122		1.1	6	117	704
113	Drain 1/2 mile south of Freitas Rd / Freitas Road Drain								151	845	748	450				549	3,291
109	Orestimba Creek at River Road^^		6.6						724	3,984	2,656	2,420				2,446	14,677
105	Spanish Grant Drain	6.0	3.6			60.4				966				23	140		
100	Ramona Lake Main Drain					1.2				755							
98	Patterson Water District Main Drain				906		91	242	151	211	368	181	302	498	2,989	243	1,455
97	Olive Avenue Drain / Eucalyptus Avenue Drain	302							91	1,238	1,107	1,153				897	5,382
94	Magnolia Avenue Drain								2	1	293	236				133	799
92	Del Puerto Creek					320		604	604	1,328	1,302	1,127	1,570			1,089	6,534
91	Richie Slough Drain				2.7		60	121	724	3,320				32	189	1,389	8,331
87	Westley Wasteway / Del Mar Drain / Grayson Road Drain / Minnie Road Drain	755				48		724	815	966	3,294	3,201	302	401	2,408	1,550	9,302
80	Hospital / Ingram Creek	3.4		10.1	13.5	18.5	60	1,328	302		1,917	1,615	483	21	127	1,129	6,774
79	Center Road Drain								151	453	302	217				281	1,684
77	Blewett Drain								181	272	942	420				454	2,722
Total		1,069	11	10	923	449	211	3,018	4,183	14,852	13,427	11,440	2,656		5,859		63,529

The first step is to estimate the volume discharged from each drain during the irrigation season and the non-irrigation season. Because no measurements are available for many months (indicated as empty cells in Table E-6), an average monthly flow is computed using the available data. This monthly average is then multiplied by six (the number of months in a season), to estimate the total flow in a season at a particular drain. Drainage flows, however, were not computed for a drain if less than two measurements were made during the season, to avoid undue bias on any single measurement. Because measurements were less extensive in the non-irrigation season, monthly average flows were computed only for six of the fifteen drains. In contrast, average flows were computed for thirteen of the fifteen drains for the irrigation season. It should also be noted that a very high flow measurement of 5,554 acre-ft in February 1987 for Orestimba Creek is disregarded. The high volume measured here is likely derived from natural runoff during a storm event from the entire Orestimba watershed, and not simply from the agricultural drainage area. The results are summarized in Table E-6.

Unfortunately, these flow estimates do not cover all drain areas. To determine flows for the total agricultural area (both non-measured and measured areas), an average drainage factor is determined for the areas where measured flow is available (Table E-7). The drainage factor is then applied to the total area. The surface drainage areas for each drain are taken from Westcot et al 1991, shown in Table E-7. The drainage factor per drain is defined as the flow per area:

Drainage Factor = (flow volume during a season) / (drain area)

Table E-7. Agricultural Surface Drainage Areas and Median Concentrations For Northwest Side

			Non-Irrigation Season (Oct 1986 - Mar 1987)			Irrigation Season (April-Sep, 1987)		
Location(s)	**Area (acres)**	**Source of Supply Water**	**Surface Drainage Factor (AF per acre)**	**EC (1987 median) (umhos/cm)**	**Boron (1987 median) (mg/L)**	**Surface Drainage Factor (AF per acre)**	**EC (1987 median) (umhos/cm)**	**Boron (1987 median) (mg/L)**
Hills Ferry Road Drain	4,500	N/A, CCID		1625	1.03	0.42	1625	1.03
Azevedo Road Drain	2,800	CCID	0.00	750	0.34	0.25	750	0.34
Drain 1/2 mile south of Freitas Rd / Freitas Road Drain	2,640	*CCID		838	0.41	1.25	838	0.41
Orestimba Creek	9,800	CCID, DMC		700	0.34	1.50	700	0.34
Marsh Rd/Spanish Grant Drain	14,740	CCID, DMC, SJR	0.01	850	0.37		850	0.37
Ramona Lake Main Drain	4,200	SJR		1500	0.86		1500	0.86
Patterson WD Main Drain	230	SJR	12.99	1450	0.94	6.33	1450	0.94
Olive Ave Drain + Eucalyptus Ave Drain	5,100	DMC, SJR		1025	0.67	1.06	1025	0.67
Magnolia Avenue Drain	530	SJR		1425	0.87	1.51	1425	0.87
Del Puerto Creek	6,400	SJR, DMC		825	0.45	1.02	825	0.45
Richie Slough Drain&								
Westley Wasteway + Del Mar Drain + Grayson Road Drain + Minnie Road Drain	8,400	SJR, DMC	0.29	1138	0.62	1.11	1138	0.62
Ingram Creek + Hospital Creek	10,060	SJR, DMC	0.01	1075.00	0.71	0.67	1075.00	0.71
Center Rd Drain	1,100	SJR		1600	1.30	1.53	1600	1.30
Blewett Drain	3,220	SJR, DMC		850	0.50	0.85	850	0.50
Total	**73,720**							
Flow weighted Concentration				**1252**	**0.76**		**788**	**0.46**
Area Weighted Drainage Factor			**0.16**			**1.01**		

For each season, an overall area-weighted average drainage factor is computed for areas measured for flow. This type of average prevents small drainage areas from overly affecting the overall average. It is given by:

$$\textbf{Area Weighted Average Drainage Factor} = \sum \frac{\textbf{(drainage factor) x (drain area)}}{\textbf{(Total Area)}}$$

For the non-irrigation season, approximately 0.16 acre-ft per acre is generated, and 1.01 acre-ft per acre is generated during the irrigation season (Table E-7). This gives an annual yield of 1.16 acre-ft per acre. Multiplying the entire 118,045 acres of agricultural area by these drainage factors, gives 18,472 acre-ft for the non-irrigation season, and 118,945 acre-ft for the irrigation season. 137,417 acre-ft is surface drained annually.

Salt and boron loads are based on a median of concentration measurements for each drain made from 1986 to 1988 (Westcot et al. 1989), as shown in Table E-7. The number of measurements per drain during this period is generally between 23 and 30. Because very few measurements were made during the non-irrigation season, no attempt is made to distinguish concentrations between seasons. This should not introduce a significant error, because the non-irrigation season flow is relatively small. Of the few measurements taken during the non-irrigation season, concentrations tended to be higher than during the irrigation season. This is probably because they were taken from very small flows. Thus using irrigation season concentrations for the non-irrigation season will tend to slightly underestimate the non-irrigation load.

For the entire NWS, a flow weighted average concentration is determined for salinity and boron for each season. It is given by:

Flow Weighted Average Conc. = Σ (median concentration) x (flow) / (Total Flow)

The flow weighted electrical conductivity is 1252 umhos/cm for the non-irrigation season, and 788 umhos/cm for the irrigation season. The flow weighted concentration for boron is 0.43 mg/L for the non-irrigation season, and 0.50 mg/L for the irrigation season.

The total seasonal flow volumes multiplied by the flow-weighted concentrations give the total loads for the NWS Sub-area. 20,114 tons of salt are discharged in the non-irrigation season, and 81,544 tons in the irrigation season. The annual salt load is 101,659 tons. 38,161 pounds of boron are discharged in the non-irrigation season, and 149,180 pounds in the irrigation season. The annual boron load is 187,341 pounds.

2. Agricultural Tile Drainage

Tile drainage loads are based on flow estimates by the Regional Board staff (Kratzer et al 1987). Seven drainage areas are considered (Table E-8), which amount to a total of 9,360 acres (Table E-8). This represents about 8 percent of the entire agricultural area in the Northwest Side Sub-area. The tile drainage factors were based on ‘rule-of-thumb’, and range from 0.65 acre-ft/acre to 0.85 acre-ft/acre. Annual flows for each tile area are computed by multiplying the drainage areas by the drainage factors. 7,210 acre-ft of tile drainage is generated annually.

Table E-8. Tile Drainage Areas and Flows in Northwest Side

Rivermile	Location(s)	Tile Drained Area (Acre)	Drainage Factor** (AF/Acre)	Annual Flow (AF)
119.5	Newman D.D. Collector Line A	600	0.85	510
117.6	Newman D.D. Collecto Line I	2500	0.85	2125
105	Spanish Grant, Moran Rd., Marshall Rd. Combined Drain	1550	0.65	1008
100	Ramona Lake Drain	1360	0.75	1020
98.6	Patterson W.D. Main Drain	1650	0.75	1238
91.4	Richie Slough Main Drain	350	0.85	298
80	Hospital Creek - Haggerman Ranch Drain	1350	0.75	1013
Total:		9360		7210
Area Weighted Average:			0.770	

The proportion of water attributed to the non-irrigation and irrigation seasons are based on seasonal patterns for surface drainage flows, derived from information in Section 1 above. 13 percent (969 acre-ft) is generated in the non-irrigation season, and 87 percent (6,241 acre-ft) in the irrigation season.

Salinity and boron concentrations, also measured by the Regional Board staff, included three extensive surveys (April and June 1986, June 1987) of subsurface drainage water being discharged from individual tile drainage systems in the San Joaquin River Basin. For this estimate, a median of all concentrations measured in the region of Stanislaus County west of the San Joaquin River is used. It is applied to both non-irrigation and irrigation season. The median salinity is 2,100 umhos/cm, and the median boron concentration is 1.15 mg/L. These concentrations are considerably higher than the concentrations for surface water drainage during the irrigation season (788 umhos/cm and 0.46 mg/L). This reflects the higher leaching of minerals that occurs as water drains through the soil to the tile drains.

Loads are computed by multiplying the flow volumes by the median concentrations. 1,771 tons of salt are tile drained during the non-irrigation season, and 11,403 tons during the irrigation season. 13,174 tons of salt is discharged annually. 3,030 pounds of boron are tile drained during the non-irrigation season, and 19,514 pounds during the irrigation season. 22,544 pounds of boron is discharged annually.

3. Ephemeral Stream Contribution

Ephemeral streams are another significant source of flow to the San Joaquin River. To make a preliminary estimate of mass loadings from the eastern slope of the Diablo Range, the Regional Board combined water quality data with average stream flow data

(Westcot et al 1991). The estimates cover natural runoff upstream of agricultural influences, with the exception of cattle grazing and grazing ponds that exist throughout much of the area. The NWS Sub-area covers 14 drainage basins, from Lone Tree Creek in the north, to Orestimba Creek in the south (Table E-9). This represents 390 square miles (249,500 acres), which is 66 percent of the total NWS Sub-area (376,941 acres).

Table E-9. Wastershed Sizes and Estimated Flows for Northwest Side

	Basin Size	**Flow (acre-ft)**				
Watershed Name	**(sq. mi.)**	Method 1	Method 2	Method 3	Method 4	Average
Lone Tree Creek	22.6	1,853	1,481	1,129	927	1,348
Hospital Creek	36.2	2,968	2,532	2,053	1,484	2,259
Arkansas-Martin Crk	12	984	601	352	197	534
Ingram Creek	20.4	1,673	1,201	820	836	1,133
Mile 33 Creek	1.6	131	89	57	26	76
Kern Creek	6.1	500	343	224	100	292
Del Puerto Creek	76.2	5,270	5,270	5,270	5,270	5,270
Black Gulch Creek	3	246	166	108	49	142
Unknown	3.7	303	209	138	61	178
Salado Creek	25.6	2,099	1,655	1,241	1,050	1,511
Little Salado Creek	9.1	746	573	419	149	472
Crow Creek	28.4	2,329	1,843	1,393	1,164	1,682
Unknown	4	328	190	105	66	172
Orestimba Creek	141	12,320	12,320	12,320	12,320	12,320
TOTAL:	**390**					**27,388**

For the larger watersheds, flow records go back as early as 1932 and end in 1987 (eg., Orestimba Creek), but generally for the smaller watersheds, the records are less extensive (eg, Kern Creek only covers 1986 to 1987). Extensive flow data is available for only 8 of the 40 watersheds in the area, so methods were needed to estimate the annual flows from the unmonitored watersheds. The results for four methods of estimation are given in Table E-9. The estimates can differ significantly between different methods. For load estimates here, the average of the four methods are used to determine a flow. The annual total flow from the NWS Sub-area is 27,388 acre-ft. Orestimba Creek represents 45 percent (12,320 acre-ft) of this.

It is estimated that of the total 27,388 acre-ft of annual flow from NWS, approximately 86 percent (23,553 acre-ft) comes during the irrigation season (April to September), and 14 percent (3,834 acre-ft) during the non-irrigation season. This estimate is based on an average monthly flow pattern derived from flow data from ten watersheds in or near the study area (Westcot et al, 1991, p. 20).

The study also estimated annual salt and boron loads for each watershed by multiplying annual flows by median concentrations for each watershed. The concentration measurements are based on Regional Board staff measurements from December 1985 to March 1988, and additional data collected by the California Department of Water

Resources and the United States Geological Survey. The median concentrations, however, are strongly biased to concentrations measured at low flows. Since low flow concentrations tend to be high, the load estimates were over-estimated considerably. The annual median concentration for the entire NWS Sub-area is 1500 uhmos/cm, which is high for natural runoff.

Because of the low flow bias, loads are estimated using flow-weighted average concentrations rather than median concentrations. The average is based on data from Appendix A of Westcot et al 1991. These averages are computed for the irrigation and non-irrigation periods (Table E-10).

Table E-10. Flow-Weighted Average Concentrations and Loads for Salt and Boron from the Northwest Side

	Flow (AF)	TDS Flow-weighted Average EC (uhmos/cm)	Salt Load (tons)	Boron Flow-weighted Average Concentration (mg/L)	Boron (lbs)
Irrigation Season**	3,834	1432	4,776	1.39	14,475
Non-Irrigation Season^	23,553	504	10,336	0.45	28,579
Annual	27,388	580	15,113	0.52	43,054

During the irrigation season, when the flows are generally low and a greater percentage of the water had percolated through the soil, the concentrations are higher: electrical conductivity is 1432 uhmos/cm, boron concentration is 1.39 mg/L. During the non-irrigation season, when runoff is much higher, the concentrations are much lower: electrical conductivity is 504 uhmos/cm, and boron concentration is 0.45 mg/L. Overall the non-irrigation season loads are higher because of the higher volume. 10,336 tons of salt and 28,579 pounds of boron are generated during this period, compared to 4,776 tons of salt and 14,475 pounds of boron in the irrigation season. 15,113 tons of salt are generated annually, which is 12 percent of the total NWS Sub-area load. 48,054 pounds of boron are generated annually, which is 17 percent of the total NWS Sub-area load.

4. Wastewater Treatment Plant Discharges

There are two wastewater treatment plants (WWTP) in the NWS: Newman WWTP and Patterson WWTP. Because discharges are applied directly to the fields, their loads have already been indirectly accounted for in the surface water drainage and tile drainage flows. Therefore, there is no need to account for the loading into the LSJR separately for this analysis. It is worthwhile however, to note what percent of salt load from agriculture is derived from the treatment plants. 1999 data from a CVRWQCB report indicates that the Newman WWTP generates 3,460 tons of salt annually, and Patterson WWTP generates 1,624 tons of salt annually. Together, this represents 5,084 tons of salt, or 4.4 percent of the total agricultural load (101,659 tons from surface water drainage plus 13,174 tons from tile drainage). Much of this salt is generated from the processing of dairy waste.

V. ESTIMATION OF GROUNDWATER SALT CONTRIBUTIONS

The original surface water balance method for calculating loads from the NWS included all groundwater accretions from both the east and west sides of the 50-mile reach of the San Joaquin River from below Mud slough to Vernalis. Groundwater contributions were not considered in the Orestimba extrapolation method (Alternate method 1) or the discrete discharge method (Alternate method 2). Consequently, the groundwater salt contributions from the west side of the river must be added to the results of the Orestimba Creek extrapolation and the discrete discharge methods to determine the total salt loading to the river. The mass balance method (original method) includes groundwater salt contributions from both the east and west sides of the LSJR. The salt contribution from east side groundwater must therefore be subtracted from the total salt loading value derived from the mass balance method in order isolate the salt loads originating from only the NWS Sub-area.

Groundwater flows, salt concentrations, and salt loads are estimated in the TMDL source analysis. These estimates are primarily based on a 1991 USGS Water Resource Investigation Report (USGS, 1991). Regional Board staff estimated that approximately 2,885 tons of salt per mile are added to the LSJR from groundwater each year. Ground water accretions to the river were partitioned into the following three regimes; 1) east side shallow groundwater; 2) west side shallow ground water; and (3) deep ground water. The deep ground water was determined to be originating in the Coast Range and flowing eastward across the valley trough as well as being discharged to the LSJR. Therefore, salt contributions from both shallow west side groundwater and the deep ground water are attributable to the NWS Sub-area. Ground water salt contributions from the east side shallow groundwater, the west side shallow ground water, and the deep ground water are presented in table E-11.

Table E-11. Estimated Groundwater Accretions and Salt Contribution to the LSJR

Groundwater Component	Flow-weighted Percent of total Flow	Flow † (CFS/Mi)	TDS (mg/L)	Salt Load (tons/mi/year)	Total salt Load†† (tons/year)
Sallow East Side	14%	0.29	698	199	9,950
Sallow West Side	24%	0.49	438	211	10,550
Deep-Coast Range	62%	1.26	2250	2792	139,60
Total				**3,203**	**160,100**
† Based on a total flow of 2.04 CFS/Mi, ††total salt load from Mud slough confluence to Vernalis based on a 50-mile reach of the LSJR.					

The total ground water loading from the NWS Sub-area is approximately 150,150 tons per year, which includes loading from both the west side shallow groundwater and the deep coast range groundwater. Salt loading from the East Valley Floor Sub-area is 9,950 tons per year which is made up entirely of shallow east side groundwater. More information on how groundwater contributions are determined is in the TMDL source analysis (section 3).

VI. RESULTS

The Orestimba Extrapolation method and the Discrete Discharge method resulted in NWS Sub-area salt load estimates of 1,000 tons/year and 130,000 tons/year respectively, excluding groundwater salt contributions. The groundwater adjusted annual average salt load from the Northwest Side ranged from 280,000 tons/year to 321,000 tons/year (Table E-12). Regional Board staff believes that the salt loading from the NWS Sub-area can reasonably be bracketed between 280,000 tons/year and 321,000 tons/year, given that the three independent methods were used to calculate salt loads from the Sub-area.

Table E-12 Comparison of calculated salt loads from the Northwest Side

Load calculation method	**Average Annual Salt Load (1000 tons/year)**	**Groundwater Salt Contribution (1000 tons/year)**	**Total Salt Load (1000 tons/year)**
(1) Mass balance method	320	-10 (east side GW)	310
(2) Orestimba extrapolation method	171	150 (west side GW)	321
(3) Discrete discharge method	130	150 (west side GW)	280

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Appendix E

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